Technical Report
October 1996

US Army Corps of Engineers
Waterways Experiment Station

Integration Requirements for the Tri-Service A/E/C CADD and GIS Spatial Data Standards

by *Robert J. Hanson, Donald E. Pittser, Michael D. Hankins*
Michael Baker Jr., Inc.

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1 Introduction

Integration Requirements of the Tri-Service A/E/C CADD and Spatial Data Standards

Background

This report has been produced to define the preferred method for the further development of the Tri-Service Architectural, Engineering and Construction (A/E/C) Computer-Aided Design and Drafting (CADD) Standards. Since their inception, the Tri-Service A/E/C CADD Standards have been developed in concert with the Tri-Service GIS Spatial Data Standards (TSSDS) for the Tri-Services Community.

The Tri-Services Community comprises the participant designers, planners, architects, engineers and other professionals with responsibility for the military facilities of the Army, Navy, Air Force and the civil works projects of the U.S. Army Corps of Engineers. In this context, throughout the development of both A/E/C CADD and Spatial Data Standards, it is recognized that the standards are intended to serve the same Tri-Service Community. However, from an implementation and application standpoint the standards are quite dissimilar in their content, framework and the breadth of information contained therein.

The A/E/C CADD Standards were developed with a different evolutionary approach from that of its sister specification. In August 1995 the Tri-Service CADD/GIS Technology Center distributed Release 1.4 of both the Tri-Service A/E/C CADD and Spatial Data Standards. The A/E/C CADD Standards were developed for engineering and design applications and provide standardized symbology, level\layer assignments, colors and similar graphic requirements in a CADD format for CADD data. Display or presentation graphics standards for CADD graphics are included, but feature (attribute) definitions are not. The Spatial Data Standards were developed as a multi purpose GIS data model that also provides standardized symbology, level\layer assignments, colors and similar graphic feature definitions *plus nongraphic attribute and domain definitions*.

As the standards have been implemented in the workplace by the Tri-Service community, the incongruity associated with the framework and content of the two standards has become very apparent to users. The differences in the standards are evidenced in the inability to easily move data contained within a compliant A/E/C CADD Standards CADD database, created for a facility or an installation, for use within applications associated with a TSSDS compliant GIS.

Moreover, the lack of attribute or domain definitions within the A/E/C CADD Standards severely restricts the use of these compliant databases for computer-aided

Facilities Management (FM) applications. Facilities management is inherently an application extension for facility CADD databases. Thus, a close relationship exists between computer-aided CADD and FM.

The International Facilities Management Association defines facilities management is the practice of coordinating the physical workplace with the people and work of an organization; it integrates principles of business administration, architecture, and the behavioral and engineering sciences. The FM functions include the development of facility plans; coordinating construction, renovation and relocation projects; purchasing furnishings, equipment and outside facility services; supervising building operations, maintenance and engineering; and managing real estate procurement and disposal. The A/E/C design and as-built drawings prepared using CADD technology can usually be associated with the cost, engineering and specification data to effectively manage facilities.

In order to support FM, a more robust model must be developed for the A/E/C CADD Standards. Figure 1 shows the interrelationships associated with the development of the A/E/C CADD, TSSDS and the FM Standards. Standards represented by a dotted outline for the boxes shown in figure 1 have not been developed or implemented by the Tri-Services to any great degree. The integration of the A/E/C CADD and Spatial Data Standards is desirable and necessary. The required standards integration will lead to a more useful model definition for the A/E/C CADD Standards and pave the way for the construction of the envisioned Tri-Service FM Standards.

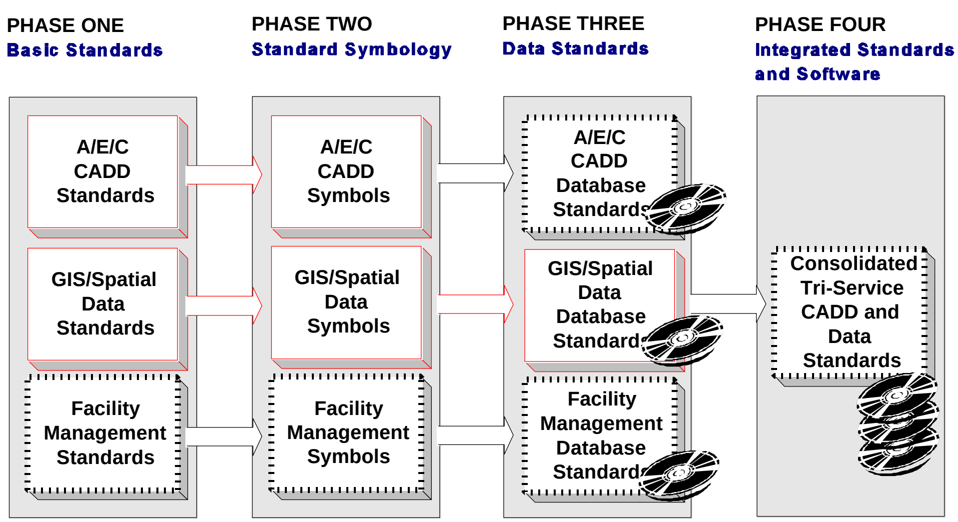

Figure 1 'Evolution of Standards'

Contained within this report is the recommended approach for the integration activity and the formula for the further development, or reengineering, of the A/E/C CADD Standards. The report outlines the envisioned entity based model for the A/E/C CADD Standards. A new evolutionary plan is defined that moves the A/E/C CADD Standards toward a common development perspective shared with the Spatial Data Standards.

The eventual benefits from integration of the standards will be the fruition of a complementary suite of Tri-Service Standards that support interoperability of data, their associated databases and applications built thereon. Figure 2 shows the desired integration of the Tri-Service Standards.

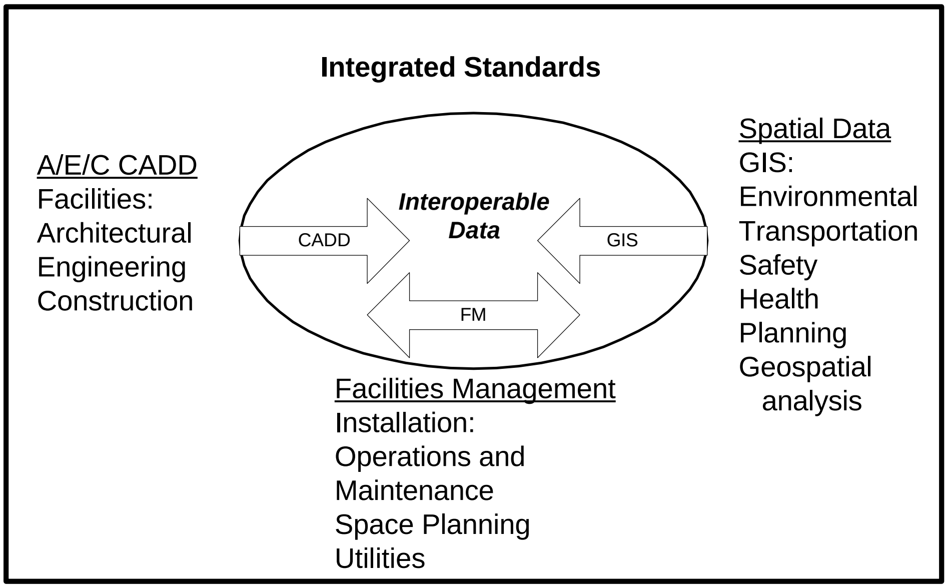

Figure 2 'Integration of Standards for Interoperablility'

However, to achieve the desired interoperability, it is necessary that the Tri-Service CADD/GIS Technology Center (the Center) work harmoniously with other organizations that are addressing similar standards initiatives. The Center participates in the initiatives of such groups as the Federal Geographic Data Committee's subcommittees, the CADD Council and monitors the developments of groups such as the Industry Alliance of Interoperability. The Center knows that standards evolve with changing needs and a need exists for an entity-based model for the A/E/C CADD Standards. The Center will continue to coordinate its standards initiatives with other organizations interested in its development activities.

Report Content

This report consists of this introduction and a narrative describing the performed evaluation of the data models used for the A/E/C CADD and Spatial Data Standards. Included in the narrative is a presentation of the structure for both standards. A subjective comparative evaluation is provided which discusses the strengths and weaknesses associated with the structure of both standards.

Composition of the standards is also discussed with a summary quantitative data assessment. This quantitative analysis expounds upon the enormity of the standards in their current state. The analysis provides important statistical data to illustrate the significant task associated with integrating the standards.

This report acknowledges that integration of the standards is necessary. However, this integration cannot be achieved immediately. To recast the A/E/C CADD Standards with a new model definition will take many months to accomplish. This work must be performed carefully to ensure that entity definitions are included in the revised A/E/C CADD Standards that are inclusive of the requirements for the civil/site, architectural, mechanical, electrical and other disciplines associated with facility design and construction. Moreover, the integration effort must expand the present set of discipline designators, discipline modifiers and groups contained within the A/E/C CADD Standards to allow for data migration to the envisioned FM Standards.

The integration methodology for migration of A/E/C and TSSDS databases built upon the A/E/C CADD and TSSDS, for use in a FM Module (standard) is explained in detail. An interim approach, or methodology, for migration of data between the two existing models is included.

In summary, he following major topics are examined in this report:

- Evaluation and comparison of the existing Tri-Service CADD/GIS Technology Center's Standards,
- The envisioned future development of the A/E/C CADD Standards,
- The future development of the GIS Spatial Data Standards,
- Considerations associated with the development of a new Facilities Management Standard,
- Methods for migration of data back and forth between projects based on different Tri-Service CADD/GIS Technology Center's Standards, and
- Translation methods for data between different CAD-2 software environments.

Participants

The following personnel participated in, and made technical contribution to, the preparation of this report.

Name	Funtion	Affiliation
Robert Hanson	Author, Editor and Technical Advisor	Michael Baker Jr., Inc.
Donald Pittser	Author	Michael Baker Jr., Inc.
Michael Hankins	Author	Michael Baker Jr., Inc.
Richard Grady	Editor	Applied Geographics, Inc.
Harold Smith	Editor and Technical Advisor	Tri-Service CADD/GIS Technology Center
Toby Wilson	Editor and Technical Advisor	Tri-Service CADD/GIS Technology Center
Bobby Carpenter	Editor	Tri-Service CADD/GIS Technology Center

2 Existing Data Model Evaluation

Data Model Comparison

A/E/C CADD Standards

The A/E/C CADD standards were developed by the Tri-Service CADD/GIS Technology Center with the intent of establishing a definitive methodology to reduce redundant A/E/C CADD efforts within the Army, Navy, and Air Force and the U.S. Army Corps of Engineers. The standards, when complete, will address the entire life-cycle of an A/E/C application from conceptualization design, through construction and facility management.

Efforts of the Center have been directed toward the development of a consolidated definitive set of A/E/C CADD drafting and presentation graphic standards. The A/E/C Standards meet requirements necessary for the creation of A/E/C design and construction documents. As outlined in Part-2 of the Tri-Service A/E/C/ CADD Standards Manual, the current release sets CADD standards specifically for the architectural, engineering, and construction disciplines of facilities development. The strategy taken satisfies guidelines necessary to integrate these standards to be used under various CADD software package applications (such as Bentley's MicroStation and Autodesk's AutoCAD) and provides for a consistent and uniform electronic deliverable. A common model is defined for A/E/C CADD drafting and presentation, whatever the CADD software package used.

Right now, the A/E/C CADD Standards are providing a viable systematic approach in dealing with A/E/C applications at the CADD level, which is a drawing file of a defined graphic composition. Figure 3 illustrates the current framework of the A/E/C CADD standards.

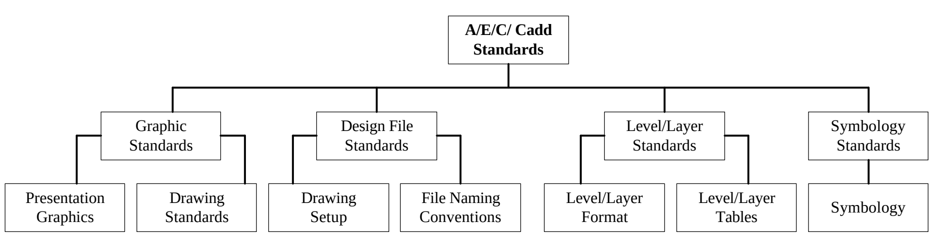

Figure *3 'A/E/C CADD Standards Structure'*

Tri-Services Spatial Data Standards (TSSDS)

The Tri-Service Spatial Data Standards (TSSDS) were developed by the Tri-Service CADD/GIS Technology Center to provide consistency in the development of geospatial databases and the subsequent sharing and access of these data within the Department of Defense (DoD). Geographic Information Systems (GIS), Automated Mapping/Facilities Management (AM/FM) and related geospatial data associated to base comprehensive planning and facility management application systems are the focal points of the standards.

There is a great diversity of computer-based spatial data systems that incorporate CADD graphics, and spatial data and the many existing databases and tabular data used within the Tri-Services. Release 1.4 of the TSSDS provides standards that incorporate not only CADD graphics data but also nongraphic data via the Spatial Data Dictionary. Figure 4 provides an overview of the TSSDS Release 1.4 structure.

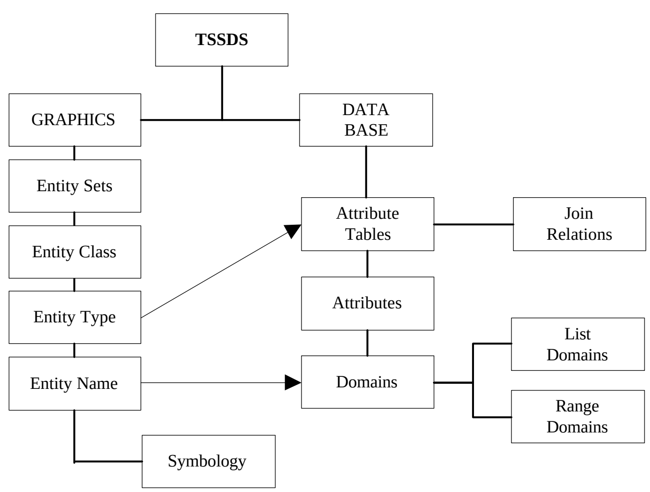

Figure 4 'TSSDS Structure'

The Spatial Data Standards data dictionary provides flexibility in the organization of data by way of an entity data model arranged hierarchialy as follows:

- *Entity Set* - the name of a generalized thematic group, the highest level of graphic and nongraphic data organized at a project level.
- *Entity Class* - the logical grouping of geographical features or entities within a given class.
- *Entity Type* - the logical name of an object that can be graphically depicted on maps.
- *Entity Name* - the individual graphic elements which are stored and represent a geospatial object or CADD graphic symbol.

TSSDS Versus A/E/C/ CADD

Careful analysis of the evolution process for the TSSDS and the Tri-Services AEC/CADD Standards results in the conclusion that the AEC/CADD Standards are far less developed than the TSSDS. The ability to use and manipulate data between these models while maintaining a consistent degree of commonality is critical to the complete integration of both standards. A framework for the A/E/C CADD Standards similar to that employed by the TSSDS's data dictionary approach will take A/E/C the full cycle from design through construction and facilities management. The first step in achieving this common goal lie in the work defined for specification of the methodology for the creation of a 'common', derivative Facility Management Specification.

Data Standards Composition

A/E/C CADD Standards

The A/E/C/ CADD Standards Manual Part 2 is divided into two distinct divisions. The first portion sets CADD drafting principles that outline the use of presentation graphics, level/layer assignments, and electronic file naming and documentation conventions. Essentially, it sets all structural format requirements necessary to develop architectural and engineering design and construction documents within the domain of an electronic CADD drafting environment.

The second portion of the Manual (Standard's Appendix D) presents standard symbology (accessible in an electronic format) that qualifies for use within an architectural and engineering construction document and is used with the practices set forth in the first portion of the manual. The symbols are categorized into 15 distinct sections that represent disciplines common to the A/E/C environment. Collectively, the CADD drafting standards and the standard symbology provide for an effective means of producing consistent CADD drawings for use within the Tri-Services.

The A/E/C/ CADD standards provide the methodology required for effective graphic document creation, consistent electronic deliverables, and the ability to work on various CADD application software platforms. However, now a void exists in the A/E/C standards for the allowance of nongraphic attribute data association with the CADD graphics. The demand for 'intelligent' drawings (electronic drawings with nongraphic data association) is a crucial subject of concern within the A/E/C community.

However, it is recognized that CADD drawings are not entirely "dumb." Mathematically speaking, they do have intelligence because the CADD technology provides for the measuring of lengths and areas and can also automatically generate CADD constructs, such as circles arcs, ellipses and spline curves. Still, the lack of definitions for attribute association in the existing A/E/C CADD Standards limits how that data can support FM. For example, space utilization (refer to figure 2) is an issuedefining application. To support space planning it is desirable to have descriptive data associated with the spaces for the personnel, furnishings and equipment contained therein (e.g., single-line floor plans with continuous topology and attribute linkages). Attribute association with the CADD model greatly increases the universe of possibilities for use of the data in space planning applications. Further development of the Tri-Service A/E/C CADD Standards requires that this attribute deficiency be confronted to promote the idea of a revised and improved entity-based data model for the A/E/C CADD Standards.

Tri-Services Spatial Data Standards (TSSDS)

The current version of the Tri-Service Spatial Data Standards (release 1.4) is delivered in Microsoft Access runtime on CD. As depicted by release 1.4, the TSSDS are intended to be data specific rather than application specific, though certain elements within the standard are constrained to conform to the lowest common capability of applications most widely used by the facilities, installations, and civil works communities within the Tri-Services. The standards employ terminology and data structures not specific to any singular software package.

The TSSDS attempts to satisfy the project life-cycle for digital data and CADD graphics by providing standardized symbology, and nongraphic, relational database tables, attributes and domains. The TSSDS is arranged in Entity Sets consisting of both graphic and tabular data related to a specific thematic or functional area, or discipline. They represent related logical groupings of related entities. Entity Class is a logical grouping of geographical features or entities. Entity types represent a collection of entities that point to a single attribute table. The attribute tables are descriptive in that they describe each entity type with attributes describing individual graphic entities.

The "partnering" of graphic and nongraphic data arranged in a logical data model, such as that defined by the TSSDS, is the key to providing installation facility managers and planners with a means to build, analyze and maintain their facilities data through the use of FM or GIS. An entity based A/E/C CADD Standard will spawn the generation of the Facilities Management Standard.

To perform the necessary analysis for the development of a redefined model for the A/E/C CADD Standards, A/E/C symbols/graphics, and TSSDS entities were selected for migration into a proposed FM module (FM Standard) based upon applicability within corresponding environments (i.e., A/E/C into TSSDS and TSSDS into A/E/C). The TSSDS entities possess a defined nongraphic data format and structure which is currently utilized by the Tri-Services, while the A/E/C CADD standards present only graphic information. The methodology exhibited by the TSSDS data structure was adopted as the standard for the FM module (as those entities in the A/E/C environment will be addressed in later research). Figure 5 serves as an example for depicting the logic of this assessment. Figure 5a shows the specific entity hierarchy for an entity class (utilities-general) that illustrates the TSSDS data structure.

A/E/C	**GIS**
Discipline Designator *Electrical*	Entity Set: *Utilities*
Discipline Modifier *Electrical Power*	Entity Class: *Utilities_Electric_System*
Minor Group *junction box*	Entity Type: *electrical_junction_point*
Symbol Name *jbox*	Entity Name *utele_junction_box_p*

Figure 5 'Logical Integration Assessment'

Quantitative Data Assessment

A/E/C CADD Standards

Facilities related features, which are defined in the A/E/C CADD Standards by symbols and presentation graphics, considered as additions to the FM module were selected from the A/E/C CADD Standards. To decide the applicability of a particular feature to the FM module we used an evaluation approach based upon explicit FM requirements. For example, DoD documents (e.g., Army Regulation 140-483, "*Army Reserve Land and Facilities Management*") that address facilities management and related applications such as Army Master Planning, Navy Shore Facilities Planning and Air Force Base Comprehensive Planning, were referred to during the evaluation. The review of the A/E/C CADD Standards was undertaken in a two-phase effort.

In phase one the Level/Layer Assignment Tables were evaluated. A total of 16 distinct A/E/C discipline matrix tables, were systematically reviewed for applicability into the FM module. Within the matrix tables 121 drawing types and 527 separate topics containing 2699 data listings were examined. The following table in figure 6 defines the individual categorization of the component disciplines and integrated parts. Appendix A includes the actual comparison tables used in the analysis.

Insert Figure 5a

Matrix Table	Topics	Data Listings
Architectural	69	311
Structural	52	214
Mechanical - Hvac	80	356
Mechanical - Plumbing	39	181
Mechanical - Fire Suppression	25	144
Mechanical - Speciality	30	173
Electrical - Lighting	17	110
Electrical - Power	37	210
Electrical - Communications	27	145
Electrical - Site	16	124
Civil/Site - General	38	211
Civil/Site - Landscape	23	172
Civil/Site - Airfields	17	166
Civil/Site - Transportation	26	193
Security	31	152
Totals	**527**	**2699**

Figure 6 'Level/Layer Table Tabulation'

Phase two of the evaluation process dealt with the examination of the definitions of features (entities) represented by Standard Symbology listed in Appendix D of the A/E/C/ CADD Standard's Manual. The group of symbols represents commonly used graphic elements used in the development of A/E/C design and construction documents. These entities are delivered in two common electronic CADD formats, cells (MicroStation) and blocks (AutoCAD), as these software platforms dominate industry-wide CADD applications. The symbols are arranged and documented in a defined A/E/C format, similar to the Level/Layer Matrix Table assignment strategy. A total of 1435 graphic elements was reviewed for inclusion into the FM module. The data table listed in figure 7 illustrates the format and selections made from each discipline category.

From within the framework of the A/E/C CADD data standards the final selection yielded 568 entities that were applicable for inclusion into the FM module. The graphic depictions in Appendix D of the A/E/C/ CADD Standards Manual served as the primary source for entity inclusions, where 488 symbol selections were made, while there were 80 entities chosen from the Level/Layer Assignment Tables.

Discipline	Symbols Reviewed	Symbols Selected
General Drafting	91	13
Architectural	179	7
Civil/Site/Landscape	11	11
Communications	3	3
Electrical	98	18
Fire Suppression	226	44
Geotechnical	4	4
Mechanical	268	8
Mechanical Plumbing	244	230
Plumbing	104	30
Security	42	28
Structural	84	13
Survey/Mapping	1	1
Utilities	80	78
Total	**1435**	**480**

Figure 7 'Standard Symbology Tabulation'

Tri-Services Spatial Data Standards (TSSDS)

Entities considered as additions into the envisioned FM module (FM Standard) were chosen from the TSSDS release 1.4, provided on CD. Several refinements to the TSSDS (available from the Tri-Services WWW Home Page) have been implemented since the distribution of release 1.4, for purposes of this research the CD-ROM version was sufficient. The evaluation criteria used for entity additions from the TSSDS dealt with conducting a thorough investigation into entity definitions, nongraphic attribute data, and graphic symbols (cells/blocks).

The entity review strategy took on a logical approach as would be undertaken from a user perspective of the TSSDS data model. Phase one of the processes was a systematic investigation of the TSSDS data model hierarchal structure. The first step involved a review of all entity sets for applicability in the FM module. Relevant entity sets were documented.

Next, the entity classes were analyzed for their relevancy within the entity sets. The review process then continued through the hierarchial data model structure to include entity types, and finally entities. At the entity level, the final selection process was made as to the actual entries designated for incorporation into the FM module. The entity section included feature definitions for the entity names and their use within the TSSDS module (i.e., _P entity descriptor indicates a point feature). Figure 8 illustrates the magnitude of the effort involved in the review activity of the TSSDS.

Information Evaluated:

Entity Sets	=	24
Entity Classes	=	78
Entity Types	=	413

Entities Selected:

*_A	=	587
*_T	=	598
*_B, *_C, *_L, *_P	=	825
Symbols	=	223

Graphic Entities:

Cells/Blocks	=	1246
Addressed	=	116

Figure 8 'TSSDS Analysis Tabulation'

The result of the TSSDS evaluation process for entity inclusion into the FM module shows that a cumulative total of 2010 entities had been selected.

Qualitative Data Assessment

The A/E/C CADD Standards model is inadequate in its current format to support the data interoperability needed by the Tri-Services CADD/GIS community. The qualitative value of the standards will be enhanced significantly if the model for the A/E/C CADD Standards is restructured similar to that of the TSSDS. That necessary restructuring begins with the examination of the integration approach with the TSSDS.

The TSSDS's arrangement of data deals primarily with GIS considerations (outside of building structures). However, the data model used for the TSSDS does allow for additional model expansion to encompass a totally integrated model for FM applications. That FM model would also be inclusive of interior A/E/C definitions plus those entity definitions necessary to support facilities management systems exclusively.

3 Integration Methodology and Migration -- AEC and TSSDS Data to a FM/GIS Module

Integration Challenge

Migration of data between the A/E/C CADD, FM and GIS application environments, in a homogenous manner, is a key goal of the Tri-Services CADD/GIS Technology Center's standards program. Since information is presently being placed in databases compliant with both the A/E/C CADD and the TSSDS, integration methods for these databases are an essential part of the A/E/C and TSSDS standards definitions. The ability to migrate data between distinct, but interrelated, application environments extend the life and value of existing data.

Recognizing that the present A/E/C CADD Standards are inadequate for the entity relationships required for spatial analysis, a method is required so that CADD data structures can be changed and reformatted to meet the demands of the FM and GIS data models. The goal for the standards is the creation of multipurpose data sets. Data created once can be used many ways to do many tasks in each of the three standards data models.

A data model definition similar to the TSSDS is necessary for the A/E/C CADD and FM standards for data to easily migrate between both the existing A/E/C graphics and GIS entities for use within the FM module. The FM module should not be defined by any physical boundary or other limitations or constraints arbitrarily imposed upon it by specific spatial characteristics. The practical implementation of a FM system requires that it project functionality from inside of a building or structure to the outside environment. In this approach, the FM module must closely adopt the operative traits of a GIS.

Integration Methodology Components

The A/E/C CADD standards were reviewed to identify entities defined by presentation graphics for applicability into the TSSDS model. Also, a similar evaluation process was used for the 2000 (+) GIS entities within the TSSDS. While conducting the review, we decided that most of the TSSDS entities had a place within the FM Module. The work flow for the A/E/C and TSSDS review is shown in Figure 9.

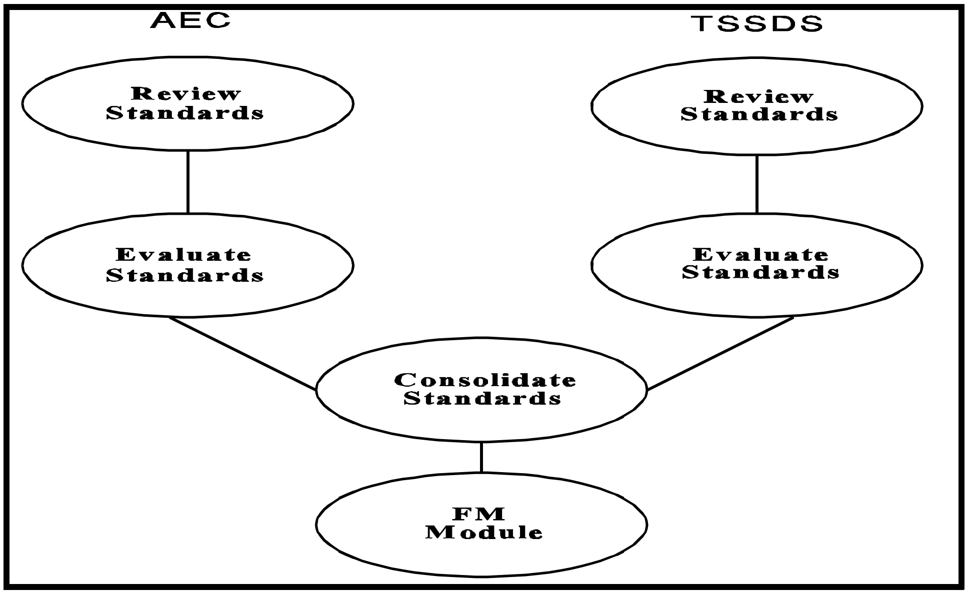

Figure 9 'Evaluation Process'

Symbol names defined in the A/E/C CADD Standards can be, to a major extent, envisioned as entity candidates for inclusion in an entity-based FM module. After examination of the characteristics associated with 1435 defined A/E/C symbols, it was found that 488 definitions qualified for inclusion into the FM module and TSSDS. The selected definitions from the A/E/C CADD were then incorporated into a Microsoft Excel spreadsheet and sorted as to description and applicability within the A/E/C grouping divisions. The selected definitions were then evaluated and compared against existing TSSDS data formats and structure to facilitate migration to the TSSDS data module. Tables 1 and 2 provide an example of the spreadsheets used to evaluate the standards.

Symbol Name	Symbol Description	Symbol Source
ffhyd	Hydrant	A/E/C STANDARDS
fibvlv	Butterfly Valve	A/E/C STANDARDS
fmeter	Meter	A/E/C STANDARDS
fkovlv	Valve Key Operated	A/E/C STANDARDS
fnsvlv	Nonrising Stem Valve	A/E/C STANDARDS

Table 1 'A/E/C Spreadsheet, Selections from Water Discipline'

Entity Name	Symbol Name	Standards Source
utwat_fire_hydrant_p	ffhyd	TSSDS
utwat_valve_p	uwvan	TSSDS
utwat_meter_p	uwmetr	TSSDS
utwat_cap_p	mpcscr	TSSDS
utwat_backflow_preventer_p	N/A	TSSDS

Table 2 'TSSDS Spreadsheet, Selections from water category'

After the initial evaluation process of defining graphics and entities from their applicability to a FM module had been made, another evaluation process was conducted. This step involved developing another spreadsheet application that showed a comparative analysis of the selections being mapped into their corresponding environments (TSSDS into A/E/C and A/E/C into TSSDS). The migration process at this point is based solely upon the commonality of a given symbol or entity as it appears in both standards. This process laid the groundwork for a comprehensive checklist of information as it appeared within the confines of both environments.

Table 3 provides an example of the spreadsheet used to compare the A/E/C CADD and the TSSDS. The first section holds symbols in the A/E/C CADD Standard that cannot be mapped to an entity in the TSSDS. The second section holds those symbols from the A/E/C CADD Standard and entities from the TSSDS that can be mapped to each other. The third section holds entities in the TSSDS that cannot be mapped to symbols in the A/E/C CADD Standards.

Entity Name	TSSDS Name	A/E/C Name	Standards Source
		uwplnt	A/E/C
		uwsoft	A/E/C
		uwvalt	A/E/C
utwat_fire_hydrant_p	ffhyd	f*hyd(6)	A/E/C;TSSDS
utwat_manhole_p	uwmhol	uwmhol	A/E/C;TSSDS
utwat_valve_p	uwvman	uwvman	A/E/C;TSSDS
utwat_sprinkler_p	nprspr		
utwat_tee_p	mptsss		
utwat_well_p	gtwell		

Table 3, 'Spreadsheet evaluation of A/E/C CADD Standard symbols and TSSDS Entities'

The differences and similarities of the selected entities and symbols became obvious as the migration process evolved. The following synopsis briefly describes the process and results of the evaluation:

1. The migration of selected applicable AEC graphic symbol representations into the TSSDS (FM Module).

(A) Selections that met the criteria and mapped directly into the TSSDS and its format.

Ex: Water Meter -
established in the AEC standards;
symbol name = uwmetr

Water Meter -
established in the TSSDS
entity name = utwat_meter_p
symbol name = uwmetr

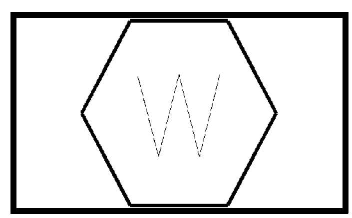

Figure 10

(B) Selections that met the criteria and map indirectly into the TSSDS and its format. Entity exists within the TSSDS but no graphic standards have been developed. Graphic standard of the A/E/C CADD should be assumed by the TSSDS.

Ex: <u>Catch Basin</u> -
established in the A/E/C CADD standards;
symbol name = ccabas

<u>Catch Basin</u> - no established graphic standard set forth within the TSSDS format.
entity name = utsto_inlet_drop_p

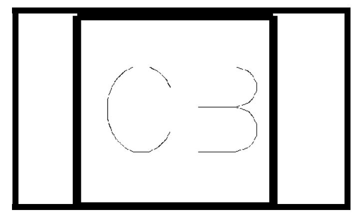

Figure 11

(C) Selections that met the criteria and did not map directly into the TSSDS and its format.

Ex: <u>Water Handhold</u> -
established in the A/E/C CADD standards;
symbol name = unhand

<u>Water Handhold</u> -
no established graphic or nongraphic standard set forth within the TSSDS format.

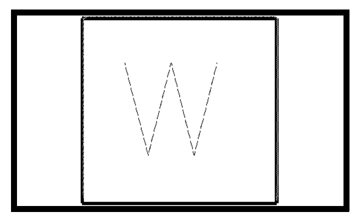

Figure 12

2. The migration of selected applicable TSSDS entity representations into the A/E/C CADD standards (FM Module).

(A) Selections that met the criteria and mapped directly into the A/E/C CADD environment as defined by the A/E/C CADD Standards, (nongraphic data structure does not currently exist in the A/E/C CADD Standards). Thus, non graphic format and structure of these entities will be assumed from the TSSDS.

Ex: <u>Water Meter</u> -
established in the A/E/C CADD standards;
symbol name = amateur

<u>Water Meter</u> -
established in the TSSDS;
entity name = uwat_meter_p
symbol name = amateur

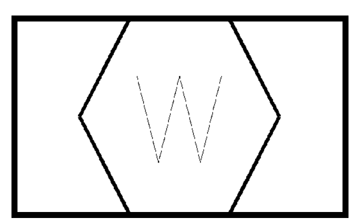

Figure 13

(B) Selections that met the criteria and did not map directly into the A/E/C CADD environment as defined by the A/E/C CADD Standards, (nongraphic data structure does not currently exist in the A/E/C CADD Standards). Thus, non graphic format and structure of these entities will be assumed from the TSSDS.

Ex: <u>Fuel Regulator</u> -
established in the TSSDS;
entity name = utful_regulator_p
no graphic standard established in TSSDS

<u>Fuel Regulator</u> -
no established standard set forth in the A/E/C CADD Standards

3. The migration of some A/E/C CADD graphic symbols and TSSDS entities into the Facility Module is complicated by the number of times a symbol is used across disciplines and categories.

(A) Selection made in the A/E/C CADD that met the criteria and mapped directly into multiple TSSDS categories and their format.

Ex: <u>Pipe Cap</u> -
established in the A/E/C CADD standards;
symbol name = mpcscr

<u>Pipe Cap</u> -
established in the TSSDS;
entity name = utwat_cap_p
= utwwt_cap_p
= utsto_cap_p
= utgas_cap_p
symbol name = mpcscr

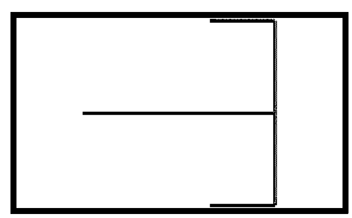

Figure 14

(B) Multiple selections made in the A/E/C CADD that met the criteria and mapped directly into a TSSDS category.

Ex: <u>Fire Hydrant</u> -
established in the A/E/C CADD standards;
symbol name = ffhyd
= fphyd
= fpphyd
= fpuhyd
= fwhhyd
<u>Fire Hydrant</u> -
established in the TSSDS;
entity name = utwat_fire_hydrant_p
= utwat_hydrant_p

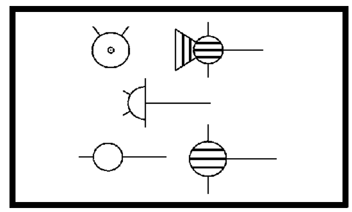

Figure 15

After creation and analysis of this correlation matrix, conclusions were derived to design an appropriate means of migrating the entity selections from both standards into the FM module.

The final TSSDS entity selections applicable for incorporation into the FM module require development of a migration strategy that satisfies the needs of both GIS and A/E/C CADD applications. Commonality must be established that serves the functionality for both environments, therefore an entity that can be co-used in a FM domain. The TSSDS entities selected for inclusion into the FM module bring a defined data format and structure already validated by the TSSDS. No defined data structure exists for the A/E/C CADD standards other than the A/E/C CADD division groups and CADD drafting standards (defined in the A/E/C CADD Standards Manual-Part 2), so a nongraphic data structure and format must be developed. A parallel data structure and defined data format, that mimic the established TSSDS data format and provide for the inclusion of data required for A/E/C CADD, is essential.

The FM model will be entity-based and possess all required attribute information needed to satisfy use in both an A/E/C CADD and GIS environment. The same familiar data structure and format present in the TSSDS will be present in the FM data model. Although the GIS entities chosen for the FM module will possess a defined data structure, they may not have a graphic representation (symbol). The following strategy is desirable for assignment of graphic symbols for required entities:

1. Adopt the graphic established by the A/E/C CADD standards if the graphic applies to the particular entity description.

2. Develop an evaluation criteria based on defined graphic standardization formats set forth by the Tri-Services (documented standards) and professional organizations (i.e., AIAASME, USGS, etc.) for acceptance of appropriate candidate symbols.

A/E/C CADD “Symbols to Entities” Selection and Corresponding Migration to a Facilities Management Module

The final A/E/C CADD symbols chosen for migration into the FM module will require a nongraphic data structure and format assigned to them. As stated earlier the data format and structure for the A/E/C CADD symbols should be based upon the existing TSSDS format. Those A/E/C CADD symbols that are common within both the GIS and A/E/C CADD environment will map over to a preexisting TSSDS standard via the FM module. Therefore these symbols will assume the GIS data associated with them as defined by the TSSDS and only the A/E/C CADD framework will need to be developed. Those graphic symbols that migrate over to the FM and are not common to both environments (i.e., A/E/C CADD derived) will require development of a complete data format and structure.

A research and evaluation process must be conducted that will provide the means necessary to construct a viable data schematic for these symbols. The format and structure development should include data definitions that will eventually fulfill the requirements for both the A/E/C CADD and GIS activities. As mentioned previously, this data format and structure will copy the methodology exhibited by the TSSDS and be accepted as the standard for the FM module.

The completion of the FM module and the associated reengineering of the applicable A/E/C CADD standards, will bridge the gap between the TSSDS and the A/E/C CADD Standards. The commonality derived from the creation of the FM module will give the user the flexibility to co-use the data from any of the Tri-Service CADD/GIS Technology Center’s Standards.

Integration Requirements and Migrating the Models

Both the TSSDS and A/E/C CADD standards are well defined, thus removing one of the most difficult elements of any migration routine which is the definition of the target and source models. However, a methodology must be established to map the existing data from one set of standards to the other. As we have already established in this research, the A/E/C CADD standards are a set of symbols and level/layer definitions (see figure 5 and figure 16).

Example: "A-WALL-EXTR-PLAN"

Major Group - (one character)
Minor Group - (four characters)
Modifier - (four Characters)
User Defined - (one to four characters)
(optional)

Figure 16 'A/E/C CADD Level/Layer Naming Methodology'

The major group categorizes the A/E/C CADD Standards into design disciplines (e.g., architectural, structural, mechanical).

The minor groups designate objects, assemblies, or construction systems such as walls, doors, ceilings, or electrical power systems

The modifier is for further differentiation of minor groups such as distinguishing full height walls from partial height walls or emergency lighting from general lighting.

The user defined section is used to further distinguish the level/layer. In the example above, the exterior wall is a plan not an elevation wall layer.

Symbols within the A/E/C CADD are defined by discipline and symbol name. For example an electrical junction box would be called EJUNBX where the first letter represents the discipline and the rest the symbol function.

A/E/C CADD sheet naming convention follows the same rules for example the first letter of a sheet name will always define its discipline. AR##PNxx.dgn is an architectural sheet.

The TSSDS is a set of entity definitions that describe the graphic display and nongraphic attribute data (see figure 5 and figure 17).

Entity Set
building
Entity Class
building_general
Entity Type
str_existing_area
Entities
bggen_structures_permanent_b

Figure 17 'TSSDS Entity Naming Methodology'

Entities within the TSSDS are organized hierarchically. The Entity Set is defined as a thematic group. Each thematic group or Entity Set is made up of several Entity Classes or themes. Each Entity Class can be made of several Entity Types and each Entity Type is made up of several Entities.

The Entities or features are the backbone of the TSSDS. They describe what the feature is going to look like graphically. They also define whether or not a database table will be linked to the graphic feature.

The Entity Class is used to define a theme within the Entity Set. In the example above the theme is building_general.

The Entity Type is used to further define the Entity Class. In the example above the type is str_existing_area.

The Entities are used to actually define the feature and its graphic display. In the example above the entity or feature is bggen_structure_permanent_b.

It is the Entity to which the A/E/C CADD standards level/layer and symbol must be mapped. By using the examples in figures 16 and 17, the A/E/C CADD information can be mapped successfully to the TSSDS format (and vice versa).

Mapping the A/E/C CADD and TSSDS Models

The symbol and level/layer definitions of the A/E/C CADD standards model can be mapped quite easily to the TSSDS and envisioned FM standard models. The way to accomplish this process is by establishing a relationship between the Disciplines (Major Groups and sometimes Minor Groups) as described in the A/E/C CADD Model to their corresponding Entity Sets and Entity Classes in the TSSDS Model. The Modifier and User positions should be mapped to the Entity itself and to the Entity Type where applicable. To map data from the A/E/C CADD model to the TSSDS successfully the entire level/layer definition should be used.

The A/E/C CADD System symbols can also be mapped to the envisioned FM model using a similar methodology. The first character of the symbol name is the discipline and the rest is the actual name of the symbol. This symbol name can be mapped to the FM Model by mapping the discipline character to the appropriate Entity Set and Entity Class for example the A/E/C CADD System symbol **EJBOX** is an electrical junction box and should be mapped to the Entity Set **Utility** and the Entity Class **Electrical**. Then the entire symbol name should be mapped to the Entity itself for example the symbol **EJBOX** should be mapped to the TSSDS entity **UTELE_JUNCTION_BOX_P**.

By using this methodology, the A/E/C CADD System Model can be successfully mapped to the TSSDS or planned FM Models. Figures 18 shows the mapping of the electrical junction box discussed above while Figure 19 illustrates the process for a building's exterior wall.

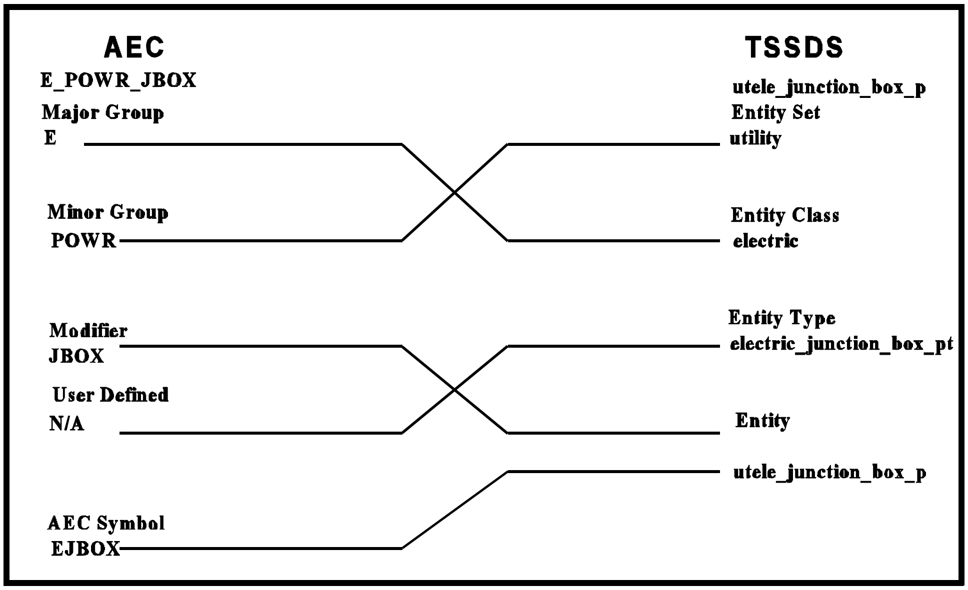

Figure 18 'Mapping the A/E/C CADD System and TSSDS Model (Level/Layer and Symbol)'

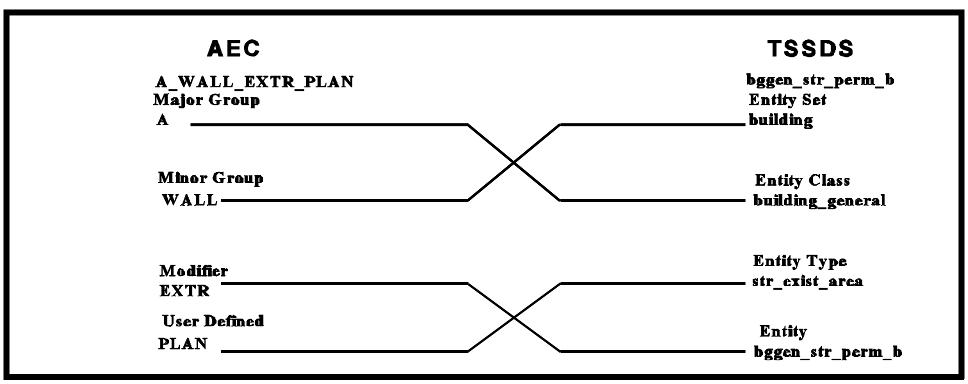

Figure 19 'Mapping the A/E/C CADD System and TSSDS Models (Level/Layer)

This described mapping methodology should enable any user to successfully move existing A/E/C CADD system symbols or level/layer definitions into the TSSDS or FM Models and by reversing the procedure the TSSDS or FM entities can be moved to the A/E/C CADD system Model.

Migrating the A/E/C CADD Data Model to the TSSDS (FM/GIS)

Until such time that there is available fully integrated A/E/C CADD, Facilities Management and Spatial Data Standards, data migration will be associated with the movement of data among the three general applications environments. Within today's operational software environment migrating CADD or geo-spatial data from one platform (CADD or GIS software system) to another, or from one application to another, is not done in a one step process. The migration requires a careful study of the source data and the target data and a proven work flow to successfully accomplish the task. Provided is summary of the multiple steps necessary to move data from the A/E/C CADD Standards to the TSSDS (FM/GIS) module as they exist today.

Migration from A/E/C CADD (DGN/DWG file structure) to TSSDS (Intergraph's MGE GIS)

1. Migrating CADD (AutoCAD files .DWG) into the TSSDS (MGE) format begins with translating the file(s) into the Intergraph (DGN) format. This can be done simply by importing a DWG file into the DGN file format. Configuration files can be written to insure the import from the AutoCAD (DWG) environment results in an Intergraph (DGN) file that meets the requirements of the FM or the TSSDS model. Once the file(s) is in Intergaph (DGN) format the migration process continues as if the file(s) has always been in the Intergaph (DGN) format.

2. Intergraph (DGN) files and AutoCAD (DWG) files reside in the A/E/C CADD system environment in a coordinate system that reflects the A/E/C CADD system project, it does not meet the needs of the FM/GIS model because the FM/GIS is based on a real world coordinate system. Before continuing with the migration this miss match in coordinate systems must be resolve. Coordinate transformation can be done by using software package such as the MGE Projection Manager. The projection software allows the user to identify common points in both models, and once the user is satisfied with the projection system to be utilized, the data originating from the A/E/C CADD system data will be transformed to match the coordinate system utilized by the FM/GIS model.

3. The A/E/C CADD system Intergraph (DGN) files should be checked to ensure the line work is correct before the file is moved into the FM/GIS data model. If only a few elements are to be processed, this procedure can be done on the computer's graphic screen in an interactive mode. However if a large file is migrating into the FM/GIS model it is best to use a line cleaner program to ensure that all over and under shoots and any duplicate line work is corrected. Any over or under shoots that exceed the tolerance set by the user when using the program will be flagged for user correction during an interactive session. After corrections have been performed, the line cleaner program should be run repeatedly, and corrections applied, to the file until there are no error flags left. This iterative process will ensure that only clean line work will make its way into the FM/GIS data model. There are several programs on the market now which do a competent job of preparing a design file for GIS application. Intergraph's MGE Line cleaner, MRF's Clean**,** and Bentley's Intersection Fixer can all be used to

prepare a file for a GIS model.

Once the Intergraph (DGN) file is clean care must be taken to ensure that the elements in the design file are targeted for the correct category within the MGE environment (e.g., no roads in a structure file). Once proper targeting is verified, the file is ready to continue in the migration process.

4. The file is now ready to be moved into the FM/GIS environment, this is done by adding the necessary linkages and records to each element in the file. Using a simple batch file the A/E/C CADD systems file can be changed to reflect the entity structure of the FM/GIS model. The batch file will send the A/E/C CADD system file to the MGE software responsible for creating features and database records (Feature Maker and Loader). This batch file can be generically written so it can be used over and over again within a migration routine, where only the input definitions and output definitions are changed per run.

5. Once migration has been completed into the FM/GIS (TSSDS) format the file name can be changed to the correct format, or the elements within the file can be moved, to an existing file already structured within the TSSDS (MGE) environment.

The migration procedures described above are for graphic information only. The A/E/C CADD system Standards do not at this time contain nongraphic (attribute information) information. However once the graphic information has been moved into the MGE FM/GIS Module it will take on the nongraphic definitions described by the TSSDS Standards. Figure 20 shows the work flow of the procedures described above.

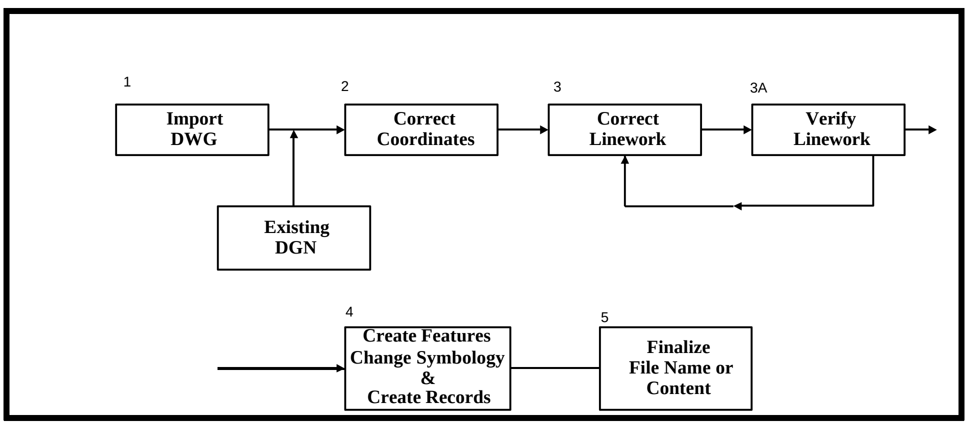

Figure 20 'Migration from A/E/C CADD System (DGN/DWG) to MGE TSSDS (FM/GIS)

Migration from A/E/C CADD system (DWG/DGN) to TSSDS (ESRI's ARC/INFO)

1. Migration for the AutoCAD (DWG) file begins with the export of the DWG file into the DXF file transfer format. The DXF file structure should contain only the layers and entities needed for the TSSDS (ARC/INFO) model. The structure should emulate the type of feature (e.g., points, lines, and polygons), found in the TSSDS (ARC/INFO) model. The ***DXFINFO*** command can be used to verify that elements in the DXF file are targeted for the correct coverage within the TSSDS (ARC/INFO) environment (e.g., no roads in a structure file). Once this is verified, the file is ready to continue in the migration process. Care should also be taken to ensure that the DWG file is as topologically clean (no under or over shoots and duplicate line work). Clean line work in can be obtained by using the one of the third party software products like TCI's MT-Clean.

Once the DXF file is ready, the coverage can be created within ARC/INFO using the ***DXFARC*** command. This command allows the extraction of any combination of layers and entities from the DXF file and places those features into individual coverages within the ARC/INFO data model.

The migration of an Intergraph (DGN) file begins with the use of such commands as MRF Line cleaner or Bentley's Intersector to insure that the line work within the Intergraph (DGN) file is clean before proceeding with the translation Once the file is clean the ***IGDSARC*** command is used within ARC/INFO to convert the Intergraph (DGN) file into an ARC/INFO coverage.

2. Once the files (DWG or DGN) are moved into the ARC/INFO coverage the ***build*** command should be used to build topology within the coverage. The build command will generate the correct topology from the translated DGN and DXF files. This command is used if the data is topologically correct (free from any over or undershoots). The ***clean*** command should be used if the original data is topologically incorrect.

3. The A/E/C CADD system (AutoCAD) model does not contain the same coordinate system as the ARC/INFO model. This problem can be rectified by running ARC/INFO's ***PROJECT*** and ***Transform*** commands to make the newly created coverages from the CADD data match the desired coordinate system of the ARC/INFO model.

4. As with any GIS (MGE or ARC/INFO) clean line work or polygons are essential for the success of the model. After the DXF or DGN file has been imported into an ARC/INFO coverage the command ***clean*** should be run to rebuild topology and correct any topological problems with the line work or polygons. Examples of bad line work would again be over or under shoots, polygons not closing or overlapping. All of these topological problems are unacceptable within the TSSDS model.

The migration procedures described above are for graphic information only.

The A/E/C CADD system Standards do not at this time contain nongraphic information. However once the graphic information has been moved into the ARC/INFO FM/GIS module it will take on the nongraphic definitions described by the TSSDS Standards. See figure 21 for a graphic work flow of these procedures.

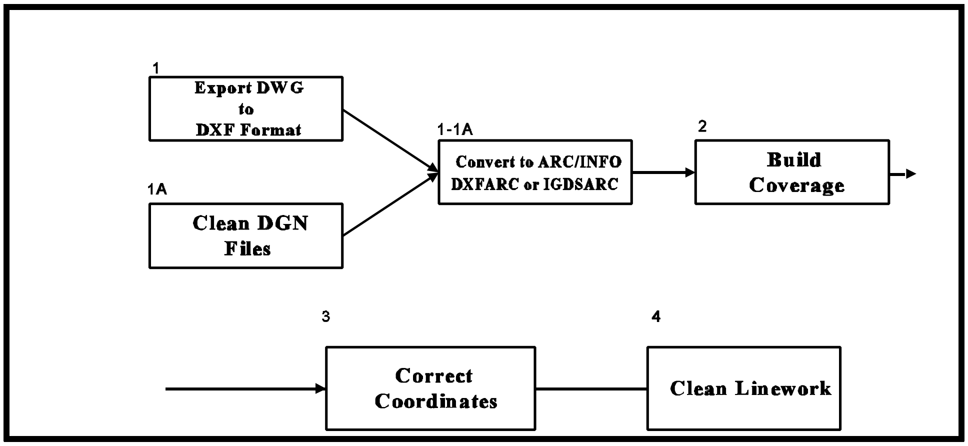

Figure 21 'Migration from A/E/C CADD System to (DGN/DWG) to ARC/INFO (FM/GIS)'

Software to Migrate Data between A/E/C CADD and the TSSDS Standards

Export and Import Software

Intergraph DWGIN / DWGOUT

Intergraph supplies two (2) methods to import/export DWG and DXF files. The first way is to use the ***Import/Export*** command while in Intergraph's graphics program environment. The user can select, while in the graphics program, the DWG or DXF file he wishes to convert. The user can, at this time, create a translation table or bring in an existing translation table which will map the DWG/DXF entities to the appropriate DGN symbology and element type. The DWG/DXF file is then converted and copied into the active DGN file. The second method is to use the command line ***DWGIN or DWGOUT*** at the system prompt. This command will convert the DWG/DXF file that is entered on the command line into a DGN file for future use within MGE and Micro station. The ***DWGOUT*** command will convert a DGN file into a DWG/DXF file for use in AutoCAD or ARC/INFO.

AUTOCAD DXFOUT

The AUTOCAD ***Dxfout*** command translates a DWG file into the DXF file transfer format These files can then be brought into DGN for further processing or moved directly into the ARC/INFO’s or MGE TSSDS (FM/GIS) module.

ARC/INFO DXFARC, IGDSARC and DXFINFO

These commands are used to convert Intergraph (DGN) files and AutoCAD (DXF) files into an ARC/INFO coverage. They are entered at the “arc: prompt” and require an input file and an output coverage. The ***DXFINFO*** command is used to view the contents of a DXF file before it is translated into ARC/INFO. This viewing option is useful when verifying the content of the file for correct coverage features.

Coordinate System Software

Intergraph MGE Projection Manager

MGE Projection Manager provides complete coordinate system conversion and transformation capabilities needed to integrate digital graphics data from different sources into a single, common coordinate system. ***MGE Projection Manager*** easily and accurately incorporates data from a wide range of projections and coordinate systems. It can also be used to integrate graphics data from unknown coordinate systems or from source materials where the coordinate system has been deformed. In addition, analysis functions provide the ability to measure and accurately display cartographic and geodetic attributes of the chosen coordinate system.

MGE Projection Manager provides interactive and easy-to-use facilities for map projection conversion and least squares derived transformations. These facilities allow the user to select graphic elements for processing and to control the scaling and rotation of text as well as special graphic structures. The map projection conversion process also supports numerous horizontal geodetic datum transformation methods. The least squares solution allows interactive entry, deletion, and modification of all control points while providing continuous update and display of transformation parameters and control point statistics.

MGE Projection Manager is a member of Intergraph Corporation's Modular GIS Environment (MGE) family of software products for complete GIS management and production.

ARC/INFO PROJECT/TRANSFORM

The ARC/INFO ***PROJECT*** and ***TRANSFORM*** commands move a map or coverage from one coordinate system to another. The ***PROJECT*** command prompts for parameters that define the map projection. The input coordinate system is read from the input coverage and the output coordinate system is defined interactively. The command can be performed interactively at the keyboard or automatically read from a text file containing the necessary parameters for execution.

The command ***TRANSFORM*** converts coverage coordinates using either a projective or an affine transformation. The command compares the original control with the projected control and performs a transformation against all feature coordinates as they are copied into a new coverage.

Line Cleaning Software

MT-Clean

MT-Clean is a third part software package that provides a fully automated process to correct the topology within an AutoCAD DWG file.
Some of it capabilities are:

1. Trims or Extends Arcs, Lines or Polylines to form intersections
2. Tract and flag all entities that fail to intersect
3. Automatically display all entities that fail to intersect for manual correction

Intergraph's MGE LineCleaner

Intergraph's ***MGE Linework Processing*** corrects errors in 2-D and 3-D digitized linework. This utility flags or fixes the invalid linework according to the options that you select and the tolerances that you provide. ***Line Cleaner***, for example**,** corrects any undershoots, overshoots and intersections. It handles lines, line strings, arcs, curves, shapes, ellipses, complex strings, and complex shapes. This process uses a list file or design file that references the unedited elements (or elements edited after a previous line cleaning process), and it outputs a new design file containing all error flags, corrected and uncorrected linework, and elements in the original design file that were not referenced by the list file.

Line Cleaner offers six options. The first three options flag (display) intersections and/or free endpoints, and the remaining three options correct the linework. The options are as follows:

1. Flag free endpoints
2. Flag intersections
3. Flag free endpoints and intersections
4. Fix free endpoints (undershoots/overshoots)
5. Fix intersections (elements intersecting themselves or other elements, such as coincident linework)
6. Fix free endpoints and intersections

MRF's Clean and Clean 3D

MRF Clean and ***MRF Clean 3D*** are multi-level, multi-tolerance 2D data cleaners. They are designed to remove or flag problems within a design file's linework.

This is done by fixing over and under shoots or flagging these problems for interactive correction. Following are some of the capabilities of ***MRF Clean***:

1. Correct overshooting
2. Correct undershooting
3. Perform line weeding
4. Remove duplicate or near duplicate points and lines
5. Create intersections in crossing linework to ease building of topology
6. Remove or flag dangles
7. Join singly connected line strings with identical attributes to form longer ones
8. Merge linework which has approximately the same geometry (conflation)
9. Identify free end points for manual review and editing

Bentley's Intersection Fixer

Intersection Fixer provides the user the capability to correct over and under shoots while the user is still in the file. The program will fix or flag the incorrect linework based on a user defined tolerance and will perform many of the functions of the software mentioned above. Some of its capabilities are:

1. Correct overshoots
2. Correct undershoots
3. Remove elements outside tolerance
4. Flag incorrect linework
5. Que the elements for correcting.

ARC/INFO Clean

The ***CLEAN*** function can analyze arcs to create new intersections and automatically resolves overshoot and undershoot errors after the file has been moved into a correct coverage compliant with the TSSDS (FM/GIS) module. The command can be used to snap arcs together, delete overshoots that fall within the tolerance, and flag any arcs that do not intersect for manual cleaning by an operator. CLEAN is a very powerful tool and users of ARC/INFO must acquaint themselves with its numerous capabilities.

GIS Translation Software

Intergraph's MGE FeatureMaker

Feature Maker creates features out of graphic elements by attaching a feature linkage to the elements. You can make features according to a specified feature or according to feature symbology. The feature must be defined in the database feature table before you run this command. If an element is already tagged as that feature, a new feature linkage is not placed on the element.

Feature Maker generates a new output design file containing all elements from the previous design file, or can optionally over-write the existing design file. This command uses transaction processing, that is, if the process fails to complete for any reason, all the transactions are undone.

Feature Maker allows you the option of inserting blank records into the database table associated with the feature and of resymbolizing the feature according to the feature definition. The mslink and mapid columns are automatically populated. If the map corresponding to the input list file does not have a record in the maps table, a zero (0) is inserted for the mapid and ***MapIdLoader*** can be run later to populate the mapid.

ARC/INFO Build

The ***BUILD*** function, within the context of this discussion, is used to generate and update correct topology from the converted DWG and DGN files. These functions are also used to create features and the feature attribute tables that store thematic data about map features. The ***BUILD*** command assumes that the data is topologically correct and to that end it does not check for dangling nodes and intersections.
The ARC/INFO ***CLEAN*** command can also be used to build topology inside an ARC/INFO coverage. The ***CLEAN*** command should be used if there is a question as to the correctness of the topology.

4 Conclusions and Recommendations

It is recommended that the A/E/C CADD Standards adopt a data model similar to that employed by the GIS Spatial Data Standards. The tasks associated with the development of the new A/E/C CADD Standards' data model will result in a development track that also forms the to the envisioned Facilities Management Standards (refer to figure 1).

The next step in the development process is to study further and define the methods, formats and the logical and physical data model for nongraphic attributes for the A/E/C CADD Standards. The following development framework should be used:

- Develop the initial framework or logical model for the nongraphic information required for design and construction attributes for the A/E/C disciplines. Data model definitions for other disciplines, such as mechanical, electrical, civil/site, can be accomplished once the initial framework has been successfully developed.

- Limit the scope of the initial development of the entity-attribute data model for the A/E/C CADD Standards to keep in step with other standards initiatives. For example, implement the development in step with initiatives undertaken by the Industry Alliance for Interoperability (IAI) and its Industry Foundation Classes - IFC Specifications.

- The realm of nongraphic attributes should be inclusive of the entity based database with domains, textural specification, shop drawings, and applicable videos (e.g., installation videos for equipment) that are integrated with the A/E/C CADD Standards.

- The data model should include methods to capture all the data (even multi-media information) of a construction project that is generated in the as-designed phase, through the construction phase, to the as-built phase in order to meet the requirements for the FM module.

- The data model must also allow for the capture of all changes to a facility or civil works construction project to include specific equipment installed, shop drawings, submitted and other such data.

- Initiatives such as the IAI's Industry Foundation Classes (IFC) can be used as a basis for identifying the candidate entities for initial development of the A/E/C CADD Standards entity-attribute data model. However, it is not recommended that an object data model be initiated or developed for the A/E/C CADD Standards at this time. The IAI's IFC initiatives are new and have not yet been widely accepted as industry standards. Presently, the proposed A/E/C CADD Standards should mirror the TSSDS data model. That same TSSDS model should be used for the development of the FM Standards.

- In addition to the IAI, the American Institute of Architects' Master Specification should be used as a guide for the definition of entities and their associated attributes, domains and ranges for the additional development of the A/E/C CADD Specification's entity attribute definitions.

As the A/E/C CADD, Facilities Management and GIS Spatial Data Standards are integrated, particular attention should be given to the development of an integrated, normalized symbol library for the three standards. In addition to the integrated symbol library, it will be useful to adopt names common to all three standards for entities and symbols. While the integration of names is not absolutely necessary, it will better facilitate the transfer of data between the data models for each standard and promote the desired interoperability.